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DESIGN AND CONSTRUCTION OF APPARATUS FOR OPTICAL SWITCH EVALUATION

Syracuse University

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Rome Air Development Center
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The goal of this effort was to develop apparatus for evaluation of optical switches relevant to digital optical computing. We state the basic aspects of optical switch evaluation (OSE) and describe appropriate general apparatus and procedures we have developed, which retains adequate flexibility to accommodate a wide variety of switches. We anticipated that such flexibility would be essential because existing switches, and ones under development, have widely varying characteristics. Our concept of the general characteristics of OSE has led us to develop an apparatus which will allow us to evaluate such switches. This report first describes the general concepts of optical switch evaluation together with the characteristics of an apparatus appropriate to implement internally consistent evaluation procedures, progress in implementing discrete components of such an apparatus, and progress in switch development.

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Abstract

The goal of this effort was to develop apparatus for evaluation of optical switches relevant to digital optical computing. We state the basic aspects of optical switch evaluation(OSE) and describe appropriate general apparatus and procedures we have developed, which retain adequate flexibility to accommodate a wide variety of switches. We anticipated that such flexibility would be essential because existing switches, and ones under development, have widely varying characteristics. Indeed, during the course of this effort a new type of switch, arrays of SEED devices, became commercially available. Our concept of the general characteristics of OSE has led us to develop an apparatus which will allow us to evaluate such switches. This report first describes the general concepts of optical switch evaluation together with the characteristics of an apparatus appropriate to implement internally consistent evaluation procedures, progress in implementing discrete components of such an apparatus, and progress in switch development.

Introduction

For all intents and purposes, we assert that an optical switch is a device which is used to control the temporal/frequency, photon number/phase, and spatial/wavevector evolution of a propagating optical wavepacket/field. Controlling these properties is the key to conveying information in a radiation field. Some switches operate actively and others passively. Permanently fixed polarization rotators/selectors, spatial filters, neutral density filters, one color/input Raman shifters, etc. are examples of passive optical devices. Certain other devices[1], which can be thought of as switches, specifically those which interchange many parrallel information containing signals with one information containing signal, eg. holograms, specklegrams and Fourier Transform lens systems, achieve high speed operation from a massive degree of parrallelism. The parrallelism of these devices involves spatial modulation of the information containing radiation field. In our view, truely passive switches have the same effect on an input signal at all times and without any correlation with a separate actuator signal. It is probable that many switches of this type can be evaluated using the apparatus under development although presently nothing more will be discussed concerning them. It will be seen below that the apparatus we describe is in fact directly applicable to the evaluation of <u>active</u> switches which implement massive parrallelism in interconnections. The main distinction to be emphasized here is active versus passive switches.

Having focussed our attention on the class of switches[2] which must be "activated" by application of a suitable optical/electrical signal, we note that various examples of fully optical switches are now becoming available[2,3,4,5] and others are under development. The simplest of all such devices will produce a single output radiation field whose characteristics depend upon the characteristics of only two seperate input fields. By fabricating such switches in arrays, as in the arrays of SEED devices which have recently become available, parallelism can be implemented. For simplicity in the subsequent presentation, we will refer to single channel devices but it must be recognized that we could be referring to arrays as well.

General Properties of High Speed Optical Switches for Optical Computing

We could say that the response of the switch, ie. some characteristic of the output radiation field, is correlated with the properties of at least two optical radiation fields which are initially present at the switch input, in accordance to some predetermined spatial and temporal protocol. We have attempted to assume nothing a priori. Instead, recognizing that switching action can be achieved via a multitude of possible effects, we have divided the possible mechanisms into classes and devised testing apparati and strategies which are compatible with each class of switch. We focussed specifically on switches which produce ultra-high speed single channel output and require only two input fields, ie. the data signal and the trigger, or actuator, signal. Upon making this decision, we note that the laws of physics[5,6,7,8,9] determine certain properties of all such optical switches and provide a rational basis for designing a very versatile apparatus for testing such devices.

First, the size of these optical switches will always be very small based on our desire to perform ultrafast information processing and the known speed of light. The actuator signal and the information signal will always be expected to be in nearly or exactly the same point in space and time at the instant any optical switch begins to operate. Thus, any apparatus which is supposed to be generally applicable to the evaluation of this class of optical switches must be able to provide the necessary optical/electrical input signals and then collect and analyze the output signal. The basic apparatus we have assembled and are currently optimizing is shown in modular form in Figure 1. The particuliar arrangement depicted is appropriate for testing a switch which accepts two optical signals as input. The first is an optical signal which actuates the switch and the second is the data to be "switched". The characteristics of these optical signals are as yet unspecified, ie. in all generality we may think of an optical signal as a wavepacket of optical radiation with specific spatial/wavevector characteristics and of undetermined frequency/temporal distribution. Additionally, this radiation is unspecified with regard to average and peak power characteristics.

Second, the meaning of the term "switching" is also somewhat vague because of the wide variety of effects which can be utilized to impress information onto a radiation field. Switching may refer to amplitude, frequency, phase, polarization or wavevector modulation, in combination or separately, which is impressed on the signal radiation field by the action of the device. The most important aspect of our choice to focus on single channel switches is that the actual effect of the switch on the data signal field is always correlated with the presence of, and properties of, the actuator or trigger input signal. <u>Thus, the act of characterizing such switches simply involves measuring and interpreting appropriate correlation functions which express the autocorrelation functions of the output radiation field, and thus the action of the switch, in terms of the spatial and temporal cross-correlation functions of the data and actuator input radiation fields.</u> The action of all switches can be represented systematically as a temporal/spatial "transfer" function which, when multiplied by the appropriate cross correlation function of the input data and actuator optical fields, gives the autocorrelation function of the output field. A complete optical switch could consist of a combination of active and passive optical components.

A computer is a combination of switches and other devices. One advantage of our approach is that by obtaining correlation functions in the process of OSE, the correlation function of a complete device, which is a combination of active and passive devices, can be expressed as products and convolutions of the correlation functions of the components. This approach can be the basis of computer modelling of optical computers much as ray tracing matrices can be used in standard optical system design. In fact, our intent was to design an OSE approach such that ray tracing matrices can be used to implement free space interconnects in an optical computer. The goal of this task was to develop apparatus for evaluation of only the active parts of optical switches. Many parameters must be specified in the context of evaluating a specific device although we can reliably anticipate a certain useful range of probable values in developing the Switch Evaluation Apparatus(SEA). Given these specifications, the basic idea of OSE is quite simple.

Specific Approach to Optical Switch Evaluation

To fully characterize optical switches as we have described them, we must measure the temporal cross-correlation function of the actuator and data optical signals. The entire approach is simply the standard pump/probe procedure which is used in picosecond/femtosecond spectroscopy experiments as a necessary preliminary to basic studies of ultrafast quantum dynamical and chemical/charge carrier kinetic phenomena. In the present case, a suitable optical data signal is applied to the switch and a suitable actuator signal is also applied. With a fixed spatial relationship between the input optical fields, the relative temporal delay between the two separate input signals is varied and the effect of the switch on some property of the output data signal is measured as a function of this relative delay. The variation of this property of the output data signal with the temporal relationship of the input signals is recorded while systematically sampling a range of spatial relationships.

The measured effect could be the change in the output data signal polarization, amplitude, phase, wavevector or frequency. A complete characterization of any optical switch would entail a measurement of appropriate temporal and spatial cross correlation functions utilizing all these observables, in addition to the properties upon which switching is supposedly based. Temporal based cross correlations relate the degree to which temporal overlap of the trigger and data determines the properties of the switched and unswitched data radiation fields. Spatial based cross correlations relate the degree to which spatial overlap of the trigger and data determines the properties of the switched and unswitched data radiation fields. For example, if temporal modulation of the data signal is being utilized, one can anticipate that shaping of the spectral density function in the frequency domain will also occur. A complete set of cross correlations may be required to insure compatibility between devices from different manufacturers which may ultimately be combined to construct more complicated devices. We would ultimately like to use the correlation functions to construct a "transfer function" for the switch. This formalism for characterizing switches is adequately general and sufficiently precise to allow comparison of all switches. A non-exhaustive example of the type of data which would contribute to a complete characterization is depicted in Figure 2.

This transfer function could be defined with respect to the measured cross correlation functions relating characteristics of the input and actuator signals to characteristics of the output signal and the independently measured autocorrelation functions of the input/output data and actuator signals. These functions, together with the material relaxation functions which characterize the switch medium itself, determine the apparatus transfer function. Having *measured* the cross correlation functions mentioned above for the optical switch, and independantly the autocorrelation functions for both the input and output optical signals, in principle, it should be possible to obtain a desired transfer function for any particuliar observable property of the switch by an appropriate deconvolution. In a later task, a formalism can be developed, consisting of mathematical definitions of the relevant observables for OSE and mathematical apparatus, to permit rational presentation and comparison of optical switch characteristics. The approach will be as phenomenological as is consistent with our understanding of the underlying physics of optical switch operation. While certainly not being exhaustive in the Figures and Captions, we have mentioned many, but not all, of the switch operation parameters which we believe may have general importance in OSE.

Progress in Implementing Discrete Components of Our SEA

Picosecond/Femtosecond Pulse Source Subsystem

Because we wish to contruct and test our SEA with specific devices, we have had to make certain choices with resp^ct to anticipating the characteristics of future generations of switches in addition to the ones we currently possess. We have focussed on designing pulse generation subsystems which operate at wavelengths in the range of 1.3-1.55 μm and roughly .6 μm. These wavelength ranges and three other wavelength ranges, ≈825 nm, 10.6 μm, and the 450-500nm ranges, are likely to be initially important for a variety of reasons.

The1.3-1.55 μm is consistent with the optimal wavelength for glass based fiber optic systems and while switches and computing functions may not be optimized at these wavelengths, communication between arithmetic logic, central processing and other functional units of an optical computer might best be implemented using such fiber. The 400-500 nm region is important for exactly the same reason except that plastic fiber is optimally utilized using that wavelength range. Thus, we have been sensitive to the problem of interconnects in our choices. In addition to the problem of interconnects it is also true that the 825 nm range is clearly important since that is the wavelength range of GaAs device operation and there is substantial activity in developing switches[10,11,12,13] using this technology. The .6 μm region is important for exactly the same reason except that it corresponds to devices[7,8] based on bacteriorhodopsin and other organic polymer materials which are currently optimized to operate in this wavelength range. Note that radiation in the range 400-500 nm is also expected to be important in the operation of such devices. We have also anticipated the appearance of switches, being developed by AT&T Bell and the Photonics Laboratory and utilizing the so-called QWEST effect[14], which are designed to operate in the 10.6 μm wavelength range.

The characteristics of the QWEST switches will require evaluation with CW CO_2 lasers and so one has been purchased. However, the data and actuator input signals needed to operate the other switches will often be pulses of radiation having duration within an order of magnitude of one picosecond. To allow synchronization of input data and actuator, we anticipate that these pulses will be produced or, in some cases, *derived*, from a single source. To test a single channel discrete switch, these pulse generation subsystems will need to be essentially milliwatt average power, and at least .1 kilowatt peak power systems. The Clark Colliding Pulse Modelocked(CPM) laser has been implemented and produces subpicosecond pulses(85 fsec FWHM) in the 600± ≈100 nm spectral range. Not to be neglected is the considerable experience in operating this device which we have accumulated in the process of implementing the laser.

We have investigated the problem of obtaining subpicosecond capability in the GaAs device spectrum, i.e. ≈ 820 nm, and have identified at least two sources with could be successful. One method involves using a different gain/saturable absorber combination, together with appropriately chosen cavity optics, in the Clark CPM. This approach has been investigated and reported in the literature[15,16] and we have obtained the needed hardware, etc. to attempt this method. Another method which has considerable promise for our application is implementation of a modelocked Ti:Saphire laser. A Ti:Saphire laser has been procured for delivery in fiscal '91. The long time needed for ground state recovery for this laser has so far precluded modelocking but there is substantial effort[17,18] being expended by a number of workers and a solution seems imminent. We have purchased such a laser and the large pulse energies expected for this device will be ideal for multiple spatial splitting which will allow *simultaneous* testing of many elements in arrays of GaAs based devices like SEEDs[19].

We have purchased and implemented a Quantronix picosecond YAG laser which has optics for 1.3, and 1.06 μm operation. In addition, the Spectra Physics 171 has been re-implemented following the relocation of the Photonics Center to the new facility in May 1989. This laser allows picosecond pulse production in the 400-500 nm range as well as synch pumping of a dye laser to produce ≈10 psec pulse production in the GaAs region. Pulse to pulse amplitude stability is clearly a goal for optimization of this system. We have also purchased an F-Center laser and INRAD frequency generation apparatus which will allow generation of picosecond pulses in the 1.5 μm and many other ranges as well. One clear advantage to having purchased such systems is that it will allow continuous tunablility over important wavelength ranges. Continuous tunability allows evaluation of the sensitivity of a switch to the wavelength integrity of the input pulses. We have clearly made considerable progress in implementing all the pulse generation subsystems, i.e. lasers, which we can reasonably expect to need for the near term, i.e. the next few years if not longer.

Input/Output Delay Line Pulse Handling Subsystems

We have designed and implemented an optical delay line which could conceivably allow optical delays between the pump and probe pulse to be varied discretely in steps of $\approx$10 fsec. The delay lines, two independant ones at this point, are composed of Klinger hardware and represent the state of the art in such equipment. A sophisticated data acquisition and manipulation computer system, using the specially designed Asyst operating system, has been interfaced to every aspect of the apparatus to allow extremely precise and reproducible procedures to implemented. More programming remains to be done but taken together, these various pieces of apparatus and equipment constitute a powerful pump-probe capability. One aspect of this subsystem which still needs to be addressed is a method for pulse picking single pulses from the modelocked train. Presently we are able to test devices which recover totally from actuator and input data pulses in less than 10 nsec. For devices which need a longer period of time to recover we will need to reduce the duty cycle of the SEA using Pockels cells or other types of devices.

Switch Mounting Subsystems

Currently this subsystem consists of a Klinger three axis, x-y-z translation mount and a modified Newport spatial filter holder. We anticipate that this approach will be useful for most switches which are intended to utilize free space interconnects. A Newport spatial filter holder was chosen because it allows precise magnetic attaching/detaching of a switch onto a stable base with at least 25 micron accuracy and in close adjustable proximity to a microscope objective. The same arrangement will be useful for fiber coupled switches since the microscope objective can be used to couple pulses into a fiber. Optical pulses would have their mutual delay and other characteristics well defined at the entrance to a fiber launching microscope objective.

Certain devices could be implemented using a local area network. Fiber is a viable approach so long as the fiber dispersion does not overly affect the temporal frequency distribution of the pulses.

Output/Input Pulse Collection Analysis Subsystems

The optical multichannel analyzer (OMA) has been implemented as has the Spiricon pyroelectric array detector. Since the OMA was procured, it has been learned how to cool both the diode array and the photocathode so as to obtain performance comparable to a CCD based device. The OMA device was purchased because it has a powerful software package. A Burleigh wavemeter has also been implemented. Direct observation of the time characteristics of pulses is desirable and a variety of photodiodes, photomultipliers, oscilloscopes and a LeCroy transient recorder have been procured.

Development of Internal Standards and Procedures for Instrument Function Determination

Some of the fastest photoinitiated responses known involve the absorption recovery of well known saturable absorbers like DODCI. Measured in a solvent jet, these simple systems are already quite well known in the literature, and could provide a highly reproducible, precise and absolute calibration of the apparatus. Equipment needed to construct a free standing jet has been procured. Various types of ultrafast laser spectroscopy such as stimulated emission pumping, spontaneous emission modulation detection by photon gating, and time resolved CARS and other four wave mixing techniques can also be attempted since all of these phenomena will provide instrument related data that could prove useful for calibration purposes. Determination of high order optical field correlation functions is highly desirable and a convenient method utilizing multiphoton ionization has been identified in the literature.

Progress in Switch Development

In addition nonlinear etalons obtained from Georgia Tech, and number of switches are under development at Syracuse University which the SEA is needed for evaluation. Switches are being developed at Syracuse University either in the Chaiken Laboratory or at the Center for Molecular Electronics .

Two kinds of switches[20,21,22,23] are now available from the Chaiken Laboratory. The first utilizes thin platinum films[24] deposited on quartz substrates and the second utilizes nonstoichiometric tungsten oxide films. Both materials are thought to be composed of 10-10^2 Å clusters[25,26,27] and preliminary studies suggest that either ruling methods or lithographic patterning could be employed to fabricate these films/switches in a Darmann grating configuration[19,28,29]. Such a configuration is thought to lend itself to reconfigurable spatial filters and similar devices. A sample of a nonstoichiometric tungsten oxide thin film deposited directly on device quality GaAs is at RB section awaiting Auger Analysis. These switches will be among the first devices we test with the evaluation apparatus we have developed. Preliminary characterization using apparatus at Syracuse is encouraging and has helped define the approach which will be taken at OP.

The Center for Molecular Electronics at Syracuse University specializes in the development of optical computing devices in general. Langmuir-Blodgett techniques and development of biological/organic materials with highly optimized nonlinear optical properties using state of the art facilities are employed in switch development. Switches based on these materials utilizing one photon absorption, two photon absorption, electric field induced second harmonic generation(EFISH) and other effects are available for characterization.

Conclusions

From the preceding synopsis, it is clear that substantial progress has been made in developing the general concepts of optical switch evaluation and the characteristics of an apparatus appropriate to implement internally consistent evaluation procedures. A conceptual basis is essential to developing OSE protocols and SEA. Considerable progress in implementing discrete components of such an apparatus, and progress in switch development, can also be seen. The amount of progress made seems remarkable considering that during the course of the effort, the Photonics Center moved to renovated facilities on base, and the Syracuse University Chemistry Department, including the Chaiken Lab and the Center for Molecular Electronics, moved to a new building on the Syracuse University campus. In spite of repeated disruptions, we are on the verge of commencing actual evaluation procedures for the switches mentioned above.

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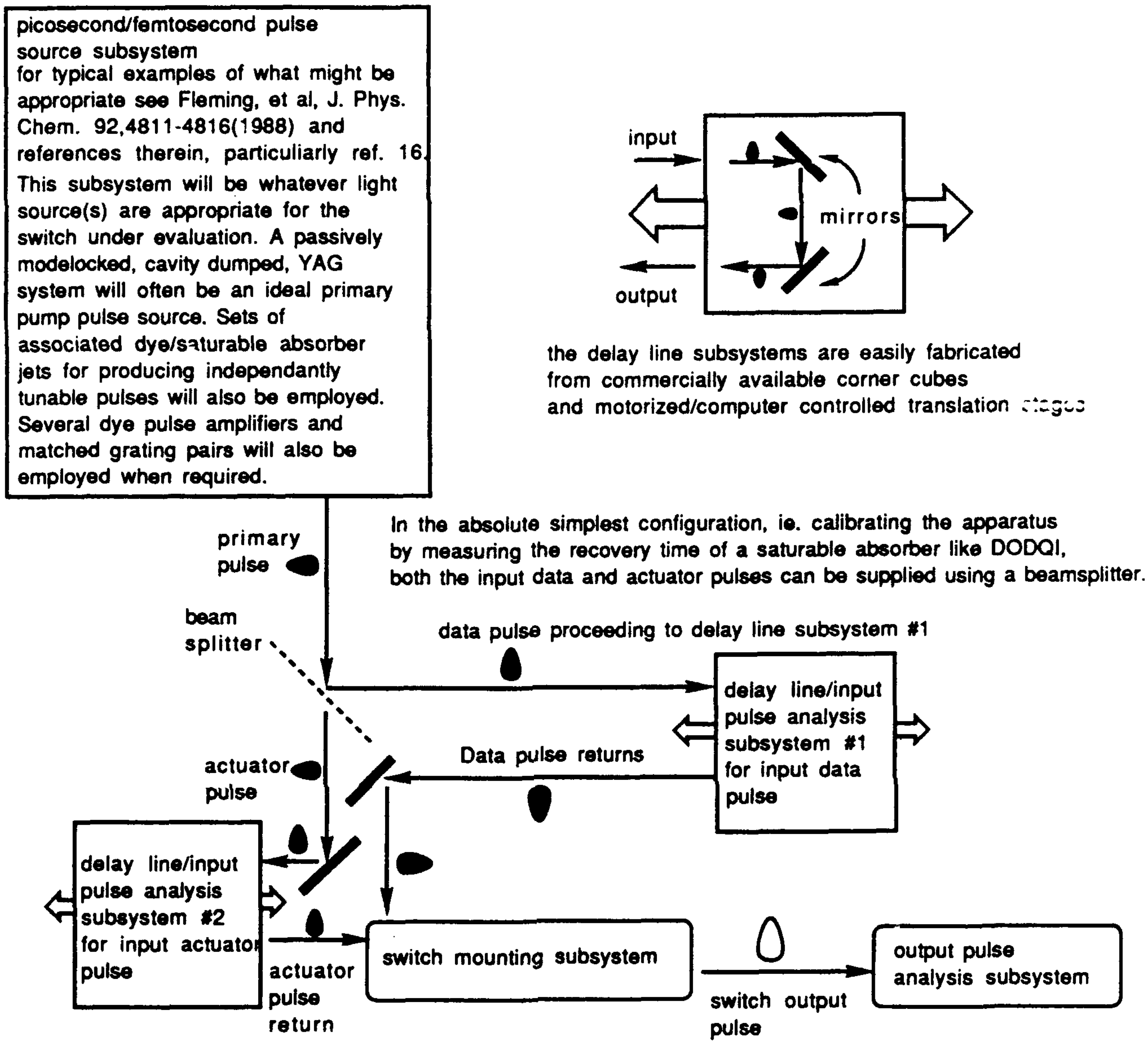
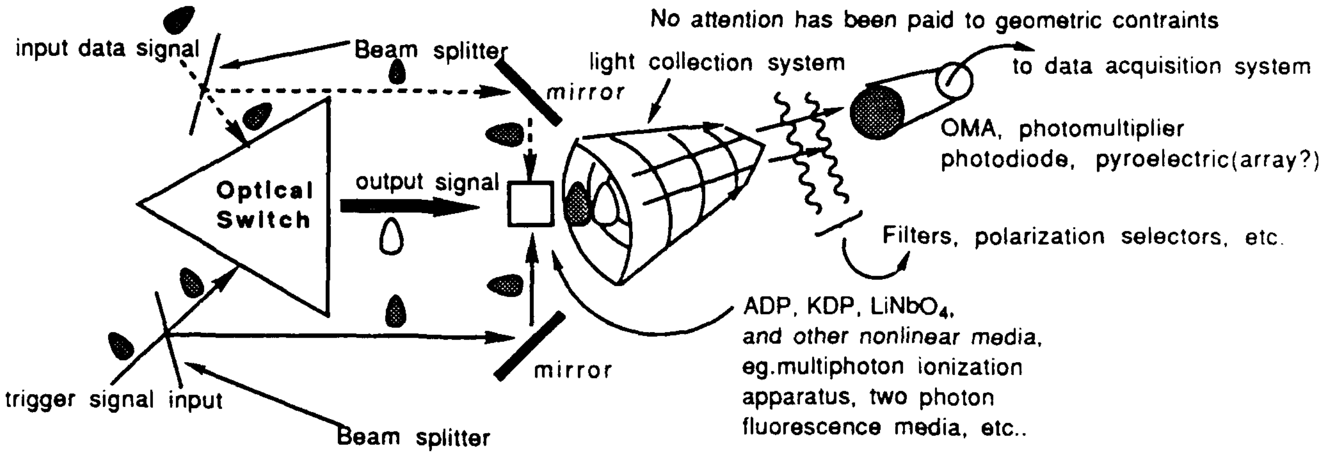
Figure 1a. Schematic Representaion of Proposed SEA



The switch mounting subsystem will vary in design from switch to switch. Given the fact that the SEA is designed primarily to provide at least two independantly tunable, and independantly characterized, pulses with well defined relative spatial and temporal properties, the mounting system could in many cases be an extensive fiber optics system designed to be compatible with a specific switch system. In other cases the mounting subsystem will consist of appropriate hardware appropriate for simulating the actual working environment of the switch under evaluation. In addition to providing the input optical/electrical signals, and hardware for coupling these signals into the devices, incorporating the ability to effectively collect and analyze whatever output or residual input signals are produced is a priority design consideration.

Output pulse analysis subsystem will consist whatever equipment is required to evaluate the effect of the optical switch. If the switch is designed to produce an output pulse which is a wavelength shifted replica of the input data pulse, provided the appropriate actuator signal was also received, then an optical multichannel analyzer interfaced to an adequate spectrograph will suffice. Alternatively the entire collection analysis system could be a linear polarization selector and a fast photodiode or pyroelectric detector.

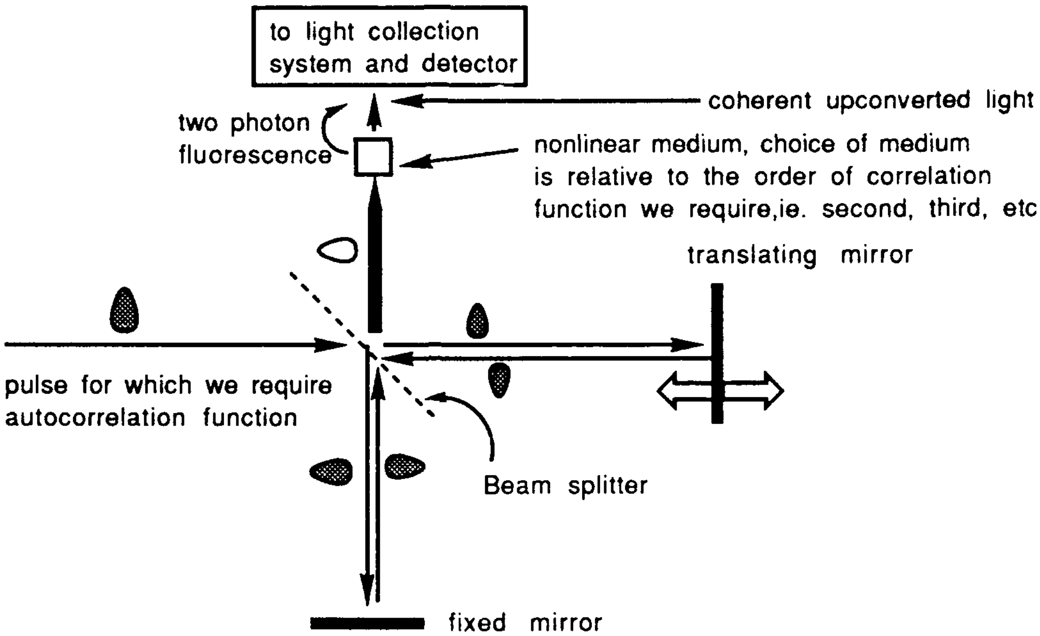
Figure 1b. Example of output pulse collection and analysis subsystem



The distance which the output data pulse must travel before it can be combined with another pulse, for purposes of obtaining correlation functions, can always be compensated for using an delay line subsystem on the sample of the input/actuator data pulse obtained just before introduction of the signals into the switch. The method of mounting switches is clearly crucial to determining the method of evaluation and will probably be one aspect of any complete basis for switch classification. Switches whose size is on the order of magnitude of 1 cm will be quite different from those which are much smaller as might be *found in the large, totally optical, computers of the future.* Larger switches may find use in primary pulse situations as might occur in multiplexing very intense light pulse trains/data streams between and among the various subsystems of a large highly parrallel optical computer. If miniaturization becomes a reality for photonic devices in any way similiar to that possible with silicon based electronics, then miniature optical waveguide/fiber optic/microscope objective hybrid technology will be a likely candidate in the first attempts to standardize evaluation of such devices. The basic aspect of this subsystem is that it will often, if not usually, not be possible to place any electronic detector in an optical data stream and obtain a simple real time record of the switch related properties. Electronic devices with adequate speed and durability with the capacity of absolute calibration to well known standards do not exist. The basic elements which are required to obtain such a real time record, using totally nonlinear optical technology, are indicated in the Figure; mirrors, lenses, etc. or the equivalent to manipulate the signals, appropriate hardware for dealing with the medium or switch, apparatus which permits measurements of the correlation properties of these signals,and adequate methods of acquiring, recording and analyzing the measurements. The above diagram gives the essential apparatus, in highly schematic and implicit form, for obtaining the cross correlation functions mentioned in the Figures which follow. The Figure below describes a simple, reliable and well known method for obtaining the autocorrelation functions.

Standard Method for Measuring Autocorrelation Functions

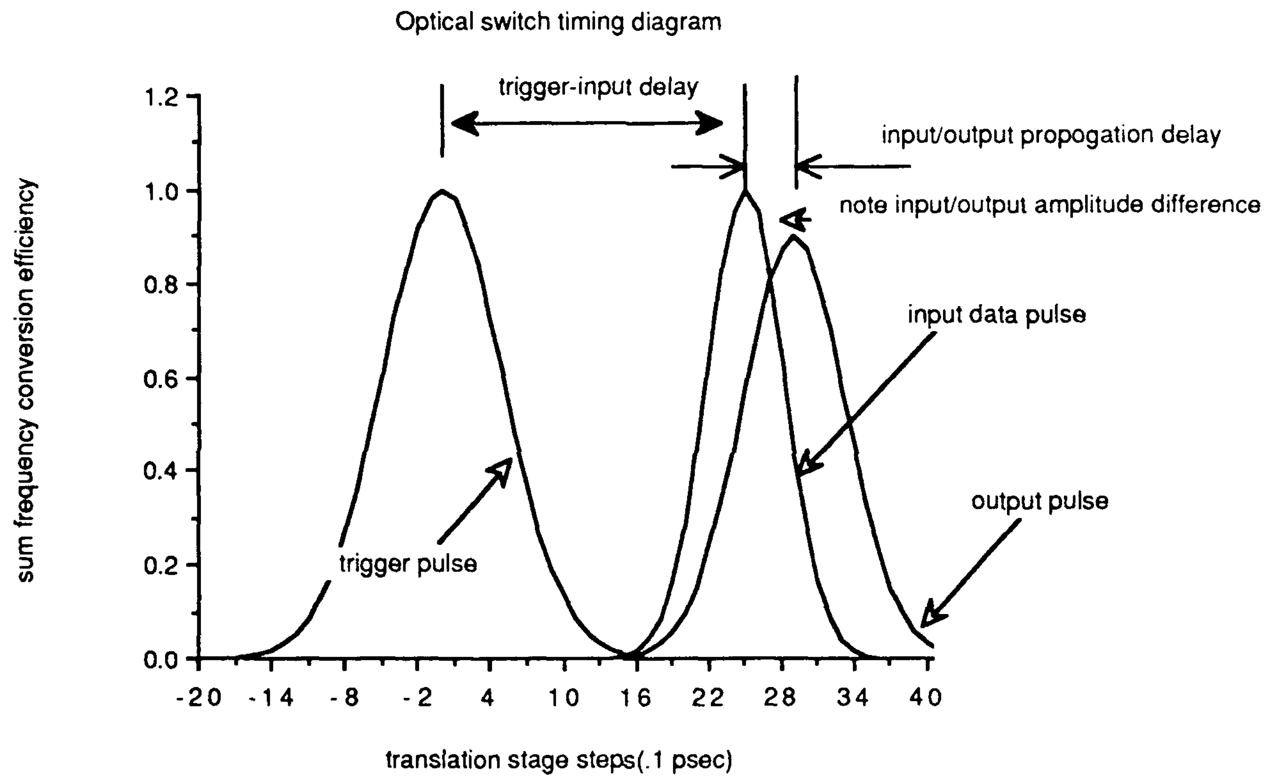
Figure 1c. Michaelson Interferometer for obtaining autocorrelation functions



The concepts of a "switching time", perhaps the smallest time between the actuator and input data arrival times to the switch which yields the intended data switching, and an "on time", perhaps the longest interval following the actuator pulse in which an appropriate input data signal will be accuratly switched, are both implicit in the timing diagram depicted below. Autocorrelation functions are absolutely required to determine the SEA temporal response function. Note that the timing diagram depicted below can be quite different from the various correlation functions which have been mentioned. The timing diagram is intended to depict the temporal relationship of the intensities of the various pulses, at a single space point, ie. ideally at some point in the switch. The correlation functions are meant to completely describe the relationship of all the observable and relevant properties of the various pulses involved in the switch. The idea of the correlation functions is to develop a function for which the action of two independant switches is the product of the independant switch transfer functions.

Figure 2a.
Sample Timing Diagram for Optical Pulses Involved in Single Output Channel, Optically Actuated, Optical Switch

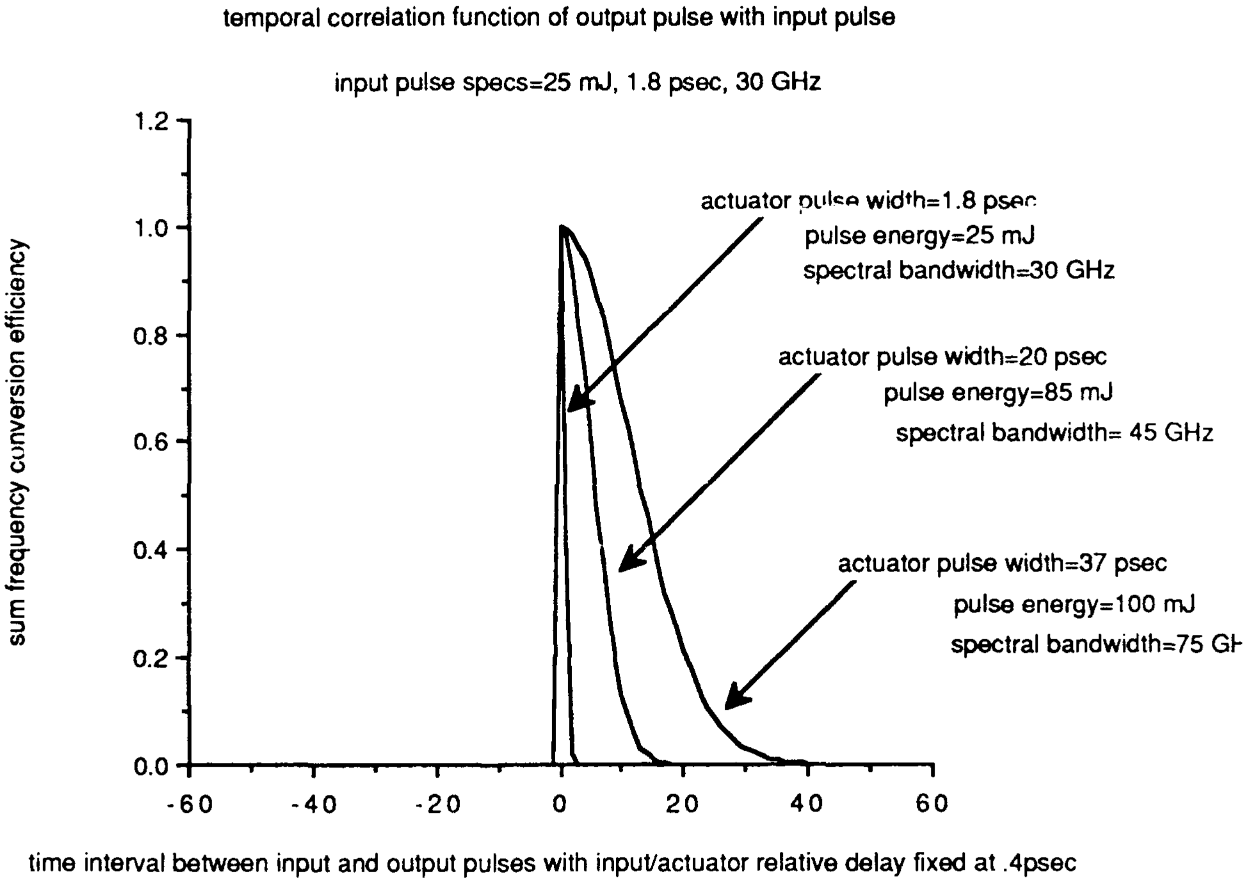
The presentation of examples of typical data is meant to give an idea of the type of measurements which will be performed and what variables may be important in evaluating possible devices and device materials. The listing is not meant to be exhaustive and all of the "data" is completely fabricated to give a rough idea of what the measurements may produce. Many details such as light wavelength, pulse repetition frequency, average power dissipation etc. are not mentioned but are certainly relevant.



This data could obtained by mixing the pulses, as if they were arriving to their entrance to the switch, with a fixed wavelength pulse, obtained from a fourth independant source, in a nonlinear crystal appropriate for sum frequency generation. If the relative times of arrival(TOA) of the different pulses to a prescribed point in space is held fixed, and the TOA of this fourth pulse is swept across an appropriate range, then the sum frequency generation efficiency, at each position in the sweep, is proportional to the appropriate temporal overlap of the respective pulses. If the three switch input pulses are of different wavelengths, then the wavelengths of the summed pulses will be easily discriminated from one another. If they are of identical wavelengths, then unambiguous identification can always be obtained via experimentation with the relative delays of each signal independantly.

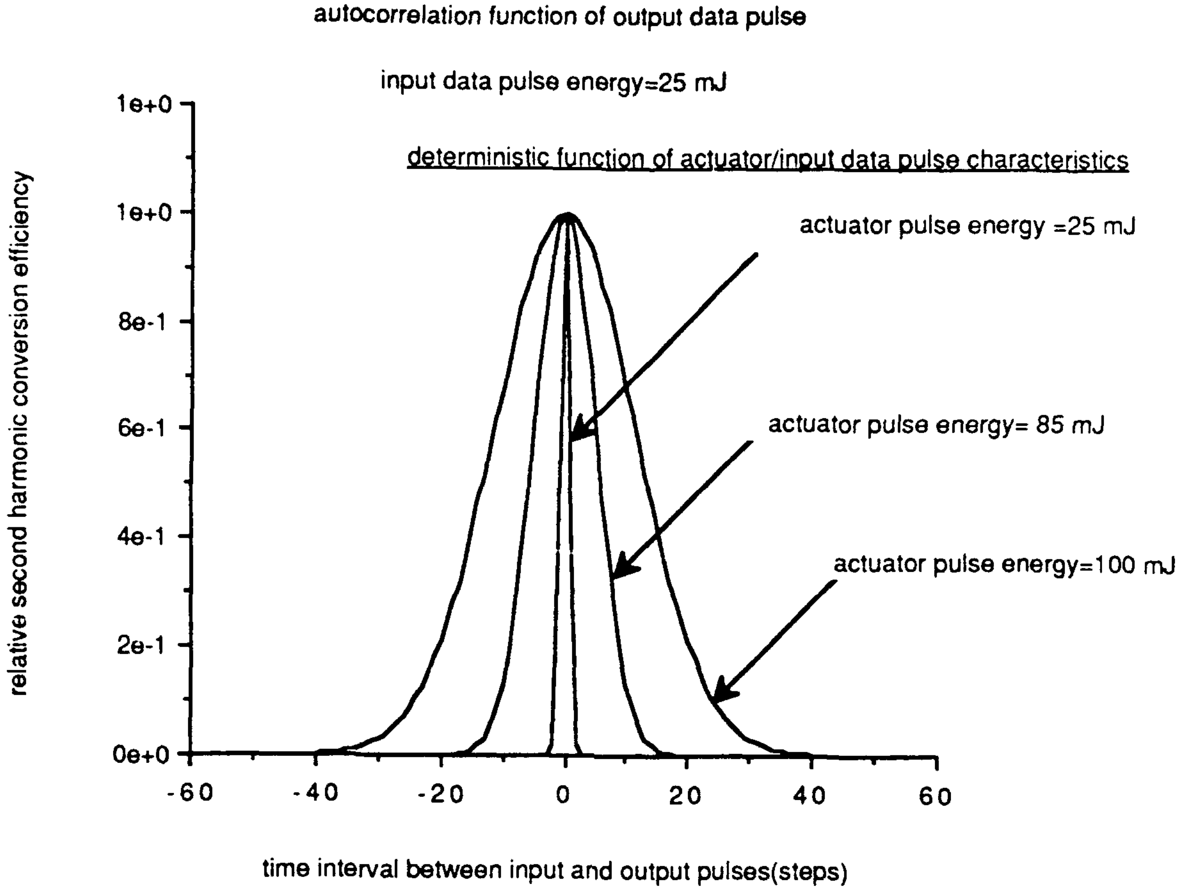
Figure 2b.

One Example of a Measurement Which Will Lead to a "Switch Response Function"



Any temporal cross correlation involving an input and the output pulse will be unsymmetrical owing to the principle of causality. An exagerated case is depicted above. Delay lines adequate to allow mixing of the leading edges of the two pulses is meant to be implicit in the Figure but the effect of unequal net dispersion experienced by the two pulses, due to unequal times of fight to the space point where the temporal cross correlation is to be measured, and other inhomegeneities, will always have to be considered. This diagram shows that the output pulse is uncorrelated with the input pulse for times less than the delay between the arrival of the input and actuator pulses to their respective switch inputs. Whether this will turn out to be the case in reality will be determined during the proposed research.

Figure 2c.


autocorrelation function of output data pulse
input data pulse energy=25 mJ
deterministic function of actuator/input data pulse characteristics
actuator pulse energy =25 mJ
actuator pulse energy= 85 mJ
actuator pulse energy=100 mJ
relative second harmonic conversion efficiency
1e+0
1e+0
8e-1
6e-1
4e-1
2e-1
0e+0
-60
-40
-20
0
20
40
60
time interval between input and output pulses(steps)

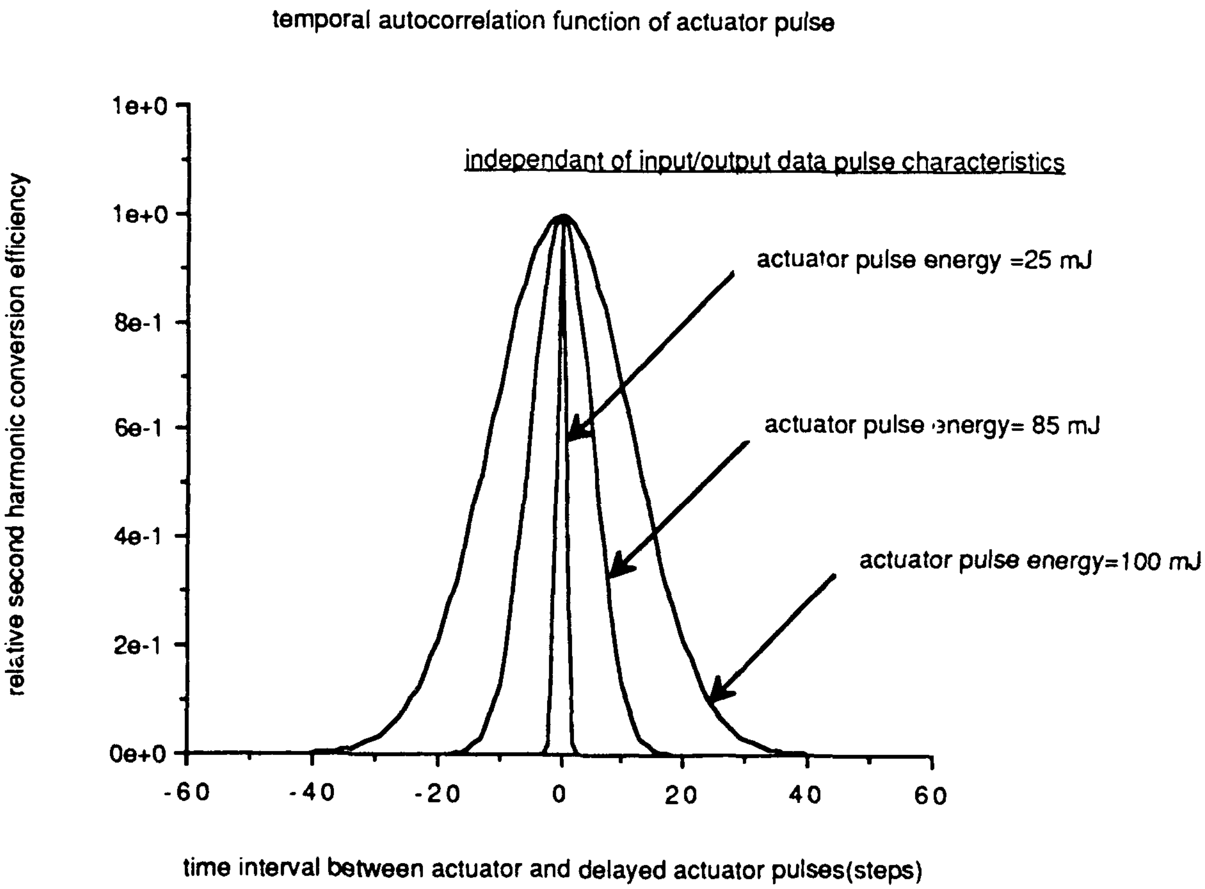
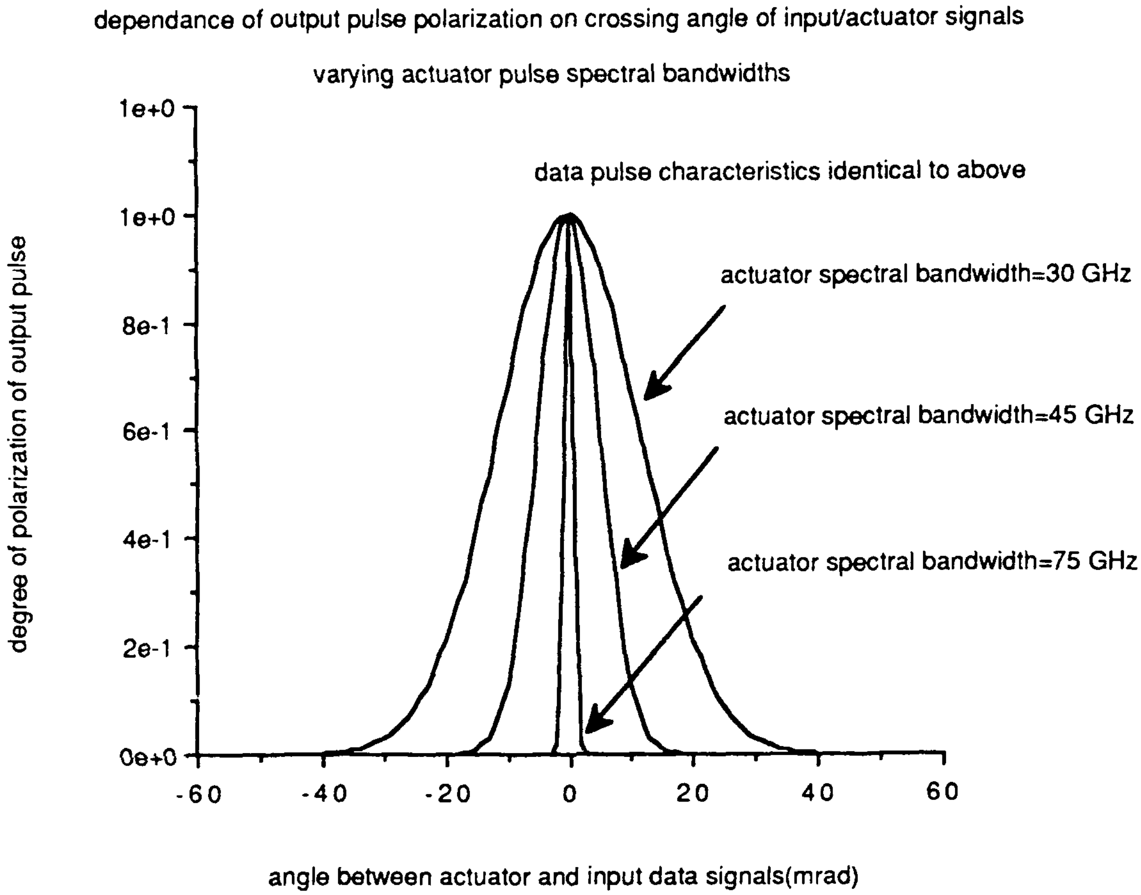

temporal autocorrelation function of actuator pulse
independant of input/output data pulse characteristics
actuator pulse energy =25 mJ
actuator pulse energy= 85 mJ
actuator pulse energy=100 mJ
relative second harmonic conversion efficiency
1e+0
1e+0
8e-1
6e-1
4e-1
2e-1
0e+0
-60
-40
-20
0
20
40
60
time interval between actuator and delayed actuator pulses(steps)

Figure 2c. continued

Example of Switch Evaluation Measurement With Regard to Spatial Parameters

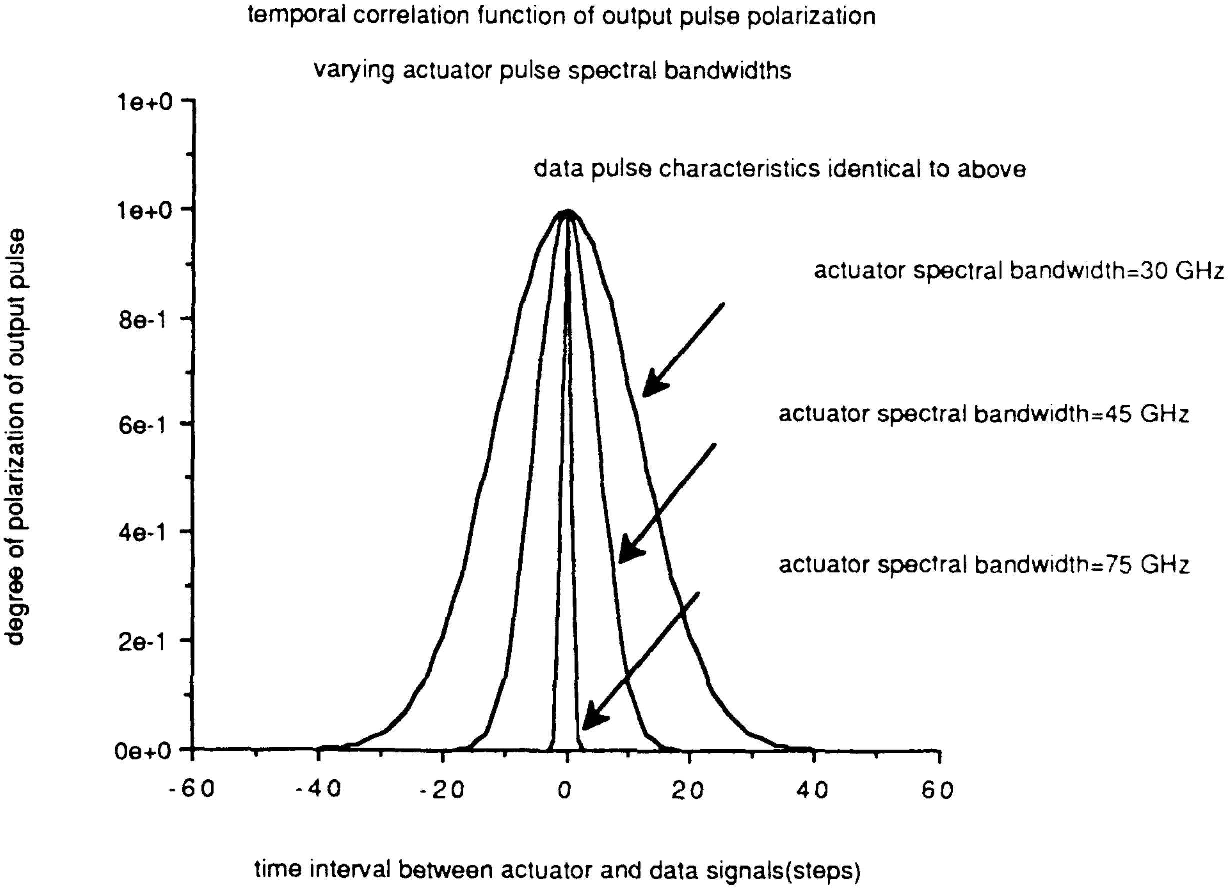


Throughout the introduction we have made an effort to group properties in terms of transform pairs, and when possible, to refer to properties in terms of experimental observables and not in terms of derived quantities. Modulation of one parameter could be manefest in other parameters and we would expect(hope) that in many cases only one half of a particuliar transform pair would require measurement. In such favorable cases, the other observable could be obtained by the appropriate transform. That such a procedure is valid will have to established in each case.

The last two parts of Figure 2 depict other types of measurements which may prove useful for evaluating switch characteristics. In every case, a switch will be "advertised" to meet certain specifications. These specifications, and whatever information that the manufacturer gives in the "owner's manual", should be sufficient to determine what form our approach to evaluation for that particuliar switch should take. Ancilliary measuements may often be indicated by the context in which the switches will actually be used, and the interrelationships between the like and unlike devices which are supposed to work together to perform composite tasks.

Figure 2c. continued

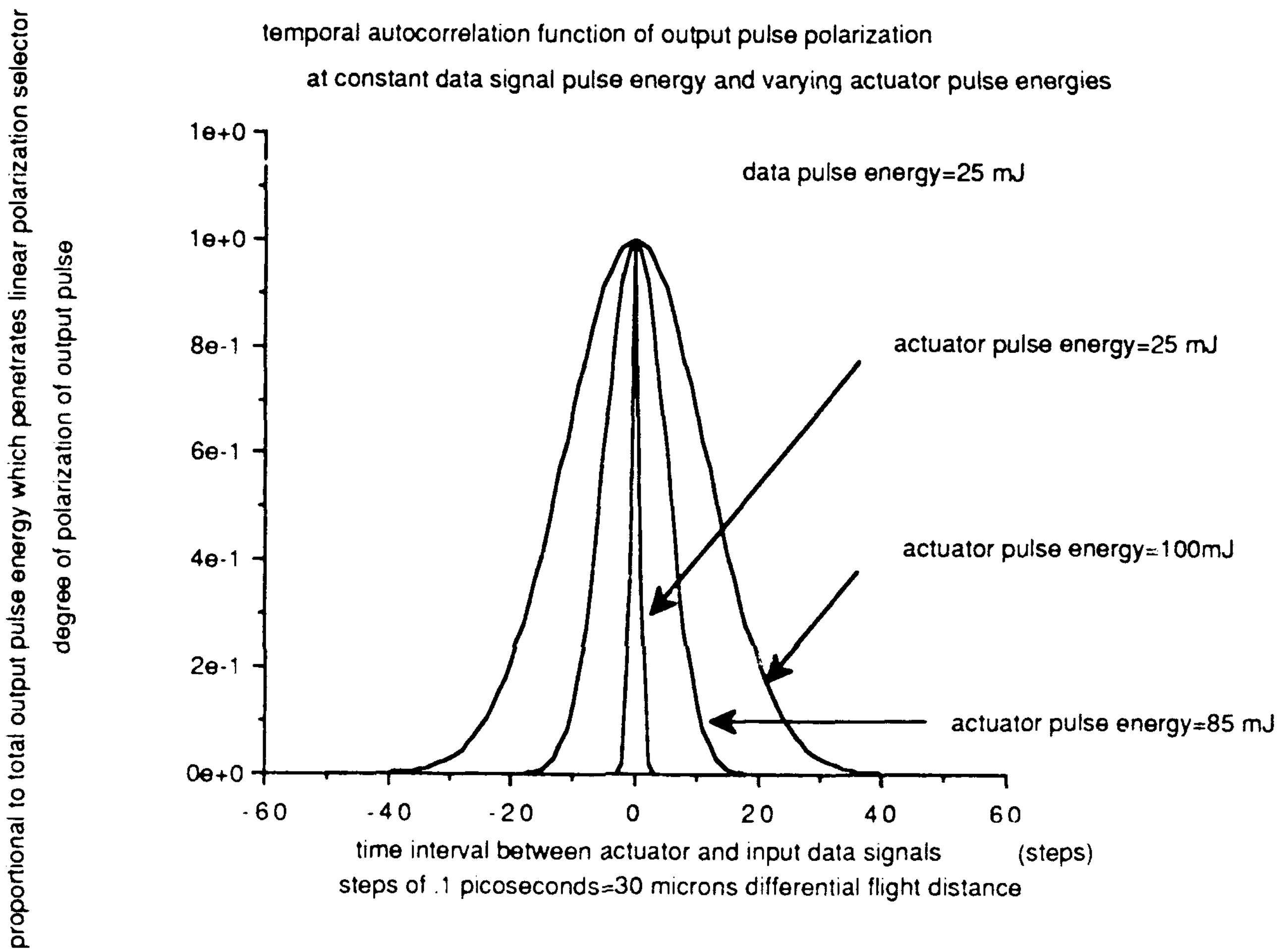
Correlation Functions Related to Possible Mechanisms of Switching



The measurements implied by the above fabricated data might be relevant in the context of evaluating an optical switch which operates using nonlinear Raman mixing of the actuator and the input data pulse to produce an output pulse. This could a CARS scheme or a scheme based on a photorefractive interaction like RIKES. In either case the spectral overlap of the actuator and the input data, with simultaneous overlap of both with a wavelength define by the switching medium, is required for operation. Given this scenario, one can anticipate that the switching efficiency would be a function of the bandwidths of both inputs and the material response function. This would therefor be a good first step in evaluating the performance of such a device. Note that the output referred to on the ordinate above could correspond to a signal which is meant to be propagated through a passive element when the switch is operating normally. The measurement above could correspond to a measurement of the unfiltered output for purposes of allowing an independant evaluation of the *polarizer.*

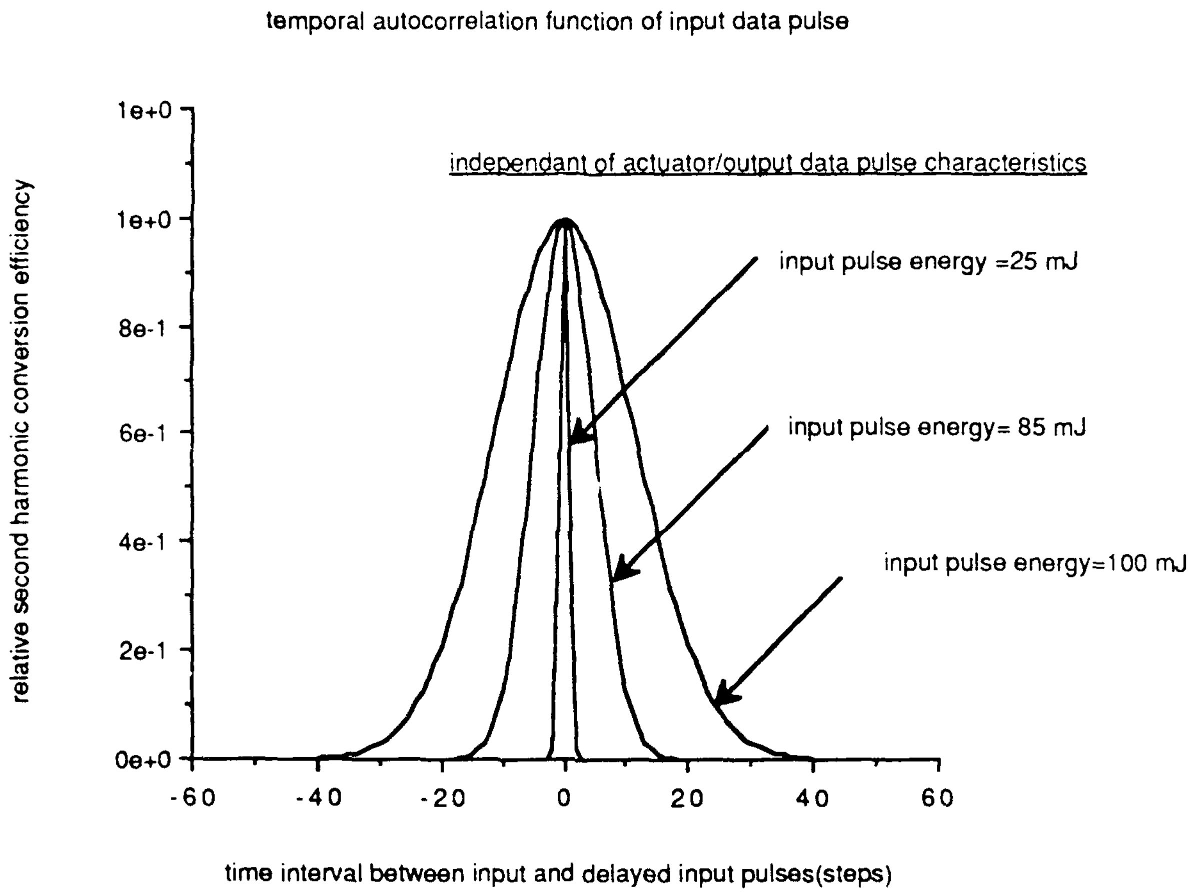
Figure 2c. continued

Correlation Functions Can Be Employed to Monitor Artifacts in the Evaluation Procedures



Its is a well known fact that it is usually difficult to change any parameter defining a particuliar laser and not change the nature of the laser light produced in more than one aspect. At the same time it can be quite difficult to sort out the various multiphoton/nonlinear optical effects which occur simultaneously in any medium which is being intensely irradiated. The operation of the switch, as well as the processes involved in switch evaluation, will both therefore be a function of the power of the light which is used in operation/evaluation. This mock data is meant to suggest this effect and the importance of such measurements.

Figure 2c. continued



The following sets of relevant measurements highlight but a few of the possible factors which will be important. The following graph describes the spatial properties of the input system of a switch. The scenario is that the switch works by producing a polarization modulated replica of the input data pulse as determined, among other possibilities, by the properties of the actuator pulse. Note that the properties of the input data pulse are assumed to be fully determined and fixed for all the graphs as indicated. While this scenario is somewhat presumptive of some details which may or may not be important for any particuliar switch, the Figure does give an example of how spatial properties of pulses, and spatial interrelationships between pulses, could be important and how the situations might be clearly and rationaly presented.

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